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Create a Mathematical Model to Estimate the Weight of Iraqi Fetuses Using Ultrasound Images

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Abstract--- Background: *Ultrasound (US) imaging is a medical imaging technique, considered one of the most used techniques in hospitals and clinical centers around the world, due to it is safe, economical, transferable, and adaptable. US imaging using to diagnosis human body parts and their functions, the most common using of US in pregnancy to monitor the developments of fetuses and revealing of abnormalities, estimation gestational age (GA), as well as estimation fetal weight (EFW). EFW is an important component of maternity health care, especially in the management and planning of the delivery mode, this will play a major role in newborn and maternal safety, EFW depend of measurement the fetal biometry such as abdominal circumference (AC), femur length (FL), bi-partial diameter (BPD) and others, accurate measurement of fetal biometry depend on the experience of sonographers. There are several models were used to EFW depending on one or more biometric of fetuses, but these models still given a some of errors in EFW in Iraq. So, this study has been carried out for creating the first EFW model for the first time in Iraq and the Middle East, a study is conducted to determine the weight of the fetus by finding a special mathematical model for the Iraqi fetuses. Depending on the US images taken from Iraqi hospitals, as will be explained in this search.*

Methods: *This study was performed in the department of Obstetrics and Gynecology in Al- Yarmouk Teaching Hospital and AL- Alawiya Teaching Hospital in Baghdad, Iraq, during 2019 on 200 pregnant women of singleton and normal pregnancies, fetal GA (36-40) week (W), and the last US scan was less than 7 days before birth. The obtained dataset (fetal biometry and actual birth weight (ABW)), were utilized to developed EFW using IBM SPSS Version 23 software package (IBM® Software).*

Results: *Statistical analysis indicated that there was a significant difference between the ABW and EFW using most weight estimation models, only our proposed model and Hadlock2 model, produced the acceptable results, where the correlation between ABW and EFW by proposed model was (R=0.964), by Hadlock2 model (R=0.920), while it extremely declined when using other models and showed less correlation. By using Hsieh model was (R=0.330), by Woo model (R=0.236), and by Jordaan model (R=0.667).*

Conclusion: *The proposed model and Hadlock2 model produce results better than other models in EFW for Iraqi pregnant, but depending on the absolute mean error (AME), absolute percentage error (APE), and R value, we conclude that, the proposed model was the best model for EFW in Iraq, and gave most acceptable results compared with ABW.*

Keywords--- *Ultrasound Imaging, Pregnancy, Fetal Biometry, Estimated Fetal Weight Models.*

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I. INTRODUCTION

Ultrasound (US) imaging is a medical imaging techniques considered to be one of the most important techniques for imaging organs and soft tissue structures in the human body, it is considered the most widely used in the medical field, because it is economical, transferable, and adaptable. US imaging used in pregnancy to obtain the fetal images from early pregnancy through the end of pregnancy to monitor the development of the fetuses. It is a routine examination during pregnancy that can be used to measure the specific biometric parameters namely abdominal circumference (AC), head circumference (HC), femur length(FL), bi-parietal diameter(BPD) and others. The specific measurement of fetal biometry lead to accurate estimation of gestational age(GA), and accurate estimation of fetal weight (EFW) [1,2].

The EFW is very important feature in order to detect the abnormalities of the fetus in initial stages of pregnancy, and it is an important component of maternity health care, especially in the management and planning of the delivery mode, that will play a major role in newborn and maternal safety. The accuracy of sonographic methods of EFW is completely dependent on the regression equations(EFW models) developed by experts and programmers into US equipment to automatic EFW. These models depend on the measurement of BPD, FL, AC, HC and some other fetal biometric parameters [3]. Hadlock's formulas (models) are commonly used for EFW, these models included in most US equipment's used in Iraq. In a study by Hadlock's et al., they found that combining of three parameters models produced more accurate results, when using only two parameters. There are many models and methods for EFW by US as shown in table (1), but these models still produce an error in EFW, which may affect the planning and management of delivery mode and maternal health [4]. In this study we proposed a new model to EFW for Iraqi pregnant women using the fetal parameters are AC, BPD, and FL.

II. ULTRASOUND IMAGINING

US imaging is a safe non-invasive procedure for diagnosing internal body organs and tissues. US imaging as compared to other imaging tools, such as computed tomography and magnetic resonance imaging, is cheaper, portable and more prevalent [5]. It has turned into a general checkup method for prenatal diagnosis. It is used to investigate and measure fetal biometric parameters, such as AC, HC, BPD, FL, and crown-rump length (CRL). Figure(1) shown the US machine using in diagnosis [6].

Figure 1: US diagnosis machine [internet web-site https://www.nationalultrasound.com/products/ge-logiq-400-pro-ultrasound-machines].

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III. FETAL BIOMETRY

Fetal biometry means the measurement of anatomic segments of the fetuses by US. Namely are: CRL is measured at sitting height, mid brain to the lowest point of breech and should be measured when the fetus is in a neutral position; FL is the most commonly obtained long bone measurement and is reproducibly measured from 13 weeks onwards; AC is a measure of fetal girth, it includes soft tissues of the abdominal wall, as well as a measure of internal organs, AC is measured on an axial plane at the level of the stomach and the bifurcation of the main portal vein into the right and left branches taking care of having a section as round as possible, not deformed by the pressure of the probe; BPD is measures the maximum distance between the two parietal bones taken from the leading edge of the skull to the leading edge i.e., outer to inner; HC is the circumference of the skull bone measured at the same level at which the BPD was measured, is taken by using the ellipsoid mode of the US machine, and adjusting the elliptical calipers to the outer margin of the fetal skull. These parameters singly or preferably in conjunction are used to monitor the fetal growth, estimation GA, as well as EFW. Figures(2) show the most common used fetal biometry [7,8].

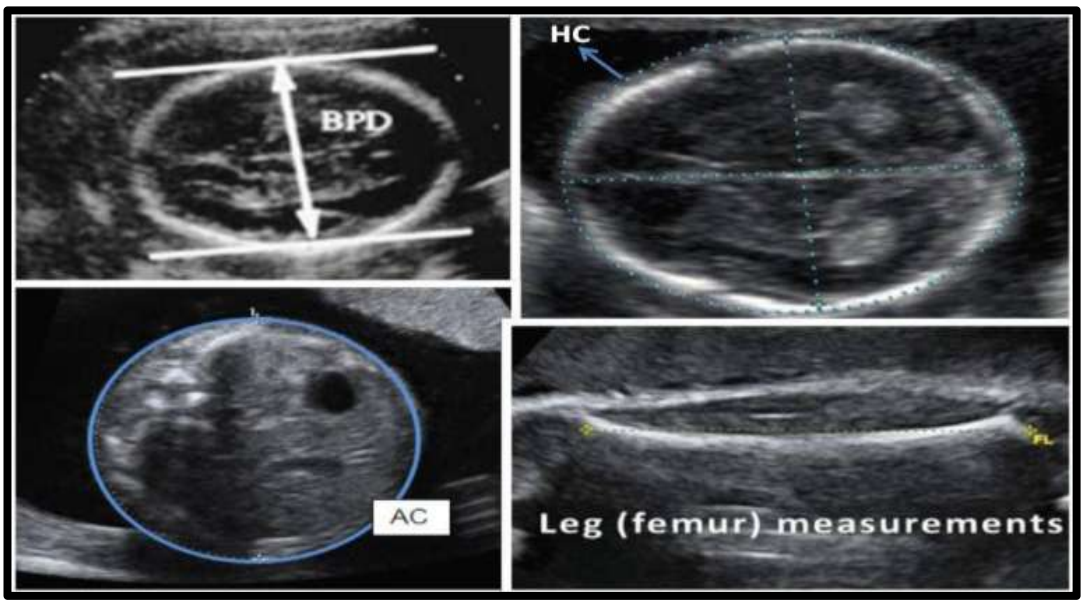

Figure 2: Shown the fetal biometric BPD, HC, AC and FL[Internet web site-
http://www.gxhospital.com/upload/2014/8/20140812093551646.jpg].

IV. METHODOLOGY

1. Material and methods

Quantitative and analytic study based on the retrospective pregnancy analysis. quantitative data were collected and analyzed to develop a new EFW model for Iraqi pregnant women, and also carry out a comparison between the proposed model and commonly used models. The study was done using retrospectively collected records of 200 pregnant women (chosen the best 80 images from a total 200 sonar images as would be displayed in Appendix), who were delivered in Al- Yarmouk Teaching Hospital and Al- Alawiya Teaching Hospital in Baghdad, Iraq, during

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2019. The inclusion criteria for the study were a live birth pregnancy, singleton pregnancy, normal pregnancy and excluded all the cases with suspected fetal malformation, fetal GA (36-40) W, and all the fetal biometry were scanned in less than seven days before birth. The selection of existing models is impractical to compare the performance of models derived from different populations with each other, but since these models are routinely used on the Iraqi population, the performance of our developed model and existing models (table1) was compared using MATLAB program(R2019a).

Table 1: Ultrasound equation models [9]

Model(parameter) Equation		
1	Hadlock2 USA (AC_FL_BPD)	Log10 (EFW) =1.335-0.0034(AC)(FL)+0.0316(BPD)+ 0.0457(AC) + 0.1623(FL)
2	Hsieh Republic of China (AC_FL_BPD)	Log10 (EFW) =2.7193 + 0.0094962(AC)(BPD) - 0.1432(FL) - 0.00076742(AC)(BPD) ^{2}+ 0.001745(FL)(BPD) ^{2}
3	Woo Hong Kong (AC_FL_BPD)	log_{10}(EFW)=1.54 + 0.15(BPD) + 0.00111(AC) ^{2} -0.0000764(BPD) (AC) ^{2} + 0.05(FL) - 0.000992(FL)(AC)
4	Jordaan S. Africa (AC_BPD)	log_{10}(EFW)= -1.1683 + 0.0377(AC) + 0.0950(BPD) - 0.0015(BPD)(AC)

2. Create fetal weight prediction model

Derived and created a new EFW model for Iraqi pregnant women based on ABW and fetal biometry. To do this, the ABW of a newborn in grams (g) was considered to be the dependent variable (DV), while three routinely used US based fetal biometry parameters, namely AC, BPD, and FL in millimeters were used as independent variables(IVs). As fetal weight gain during intrauterine life is exponential in nature, it has been observed that US based IVs correlate most closely with (log_{10}) transformed values of birth weight. Therefore, $log_{10}$of ABW was used as the dependent parameter for model derivation [10]. The best 80 images were chosen from a total of 200 images to create EFW model. The study population (N=80) was randomly split into two subgroups: a training set (60 case), and a validation set (20 case). Where the training set used to derive new model for EFW depending on multiple linear regressions by using $IBM^{®}$ Software, while the validation set was used to test the performance of the generated model, as well as to compare it against the performance of the existing EFW models. Multiple linear regression is carried out to form the relationship between a dependent DV and IVs. The general equation of multiple linear regression given by equation(1), [11]:

$$Y=B_{\circ}+B_1X_{1\,i}+ B_2X_{2\,i}+B_3X_{3\,i} +..........+ B_PX_{P\,i} \quad (1)$$

Where:($B_{\circ}$) is the constant term, (B_1 to B_p) are the coefficients relating the (p) explanatory variables to the variables of interest, (Y) is DV, and ($X_{1\,i}$ to $X_{P\,i}$) are IVs.

3. Statistical analysis

Based on the collected dataset(fetal biometry and ABW), a multiple linear regressions were used to develop our proposed model, the obtained fetal biometry were subjected to statistical analysis using IBM SPSS Version 23 software package ($IBM^{®}$ Software). where fetal biometry were regarded as IVs, while the fetal variable AFW was

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regarded as the DV. The inferential statistics namely t-test and ANOVA were performed. Independent samples t-test was used to assess significant difference between means of two groups, while ANOVA was used if more than two groups were involved, other statistics as standard deviation, correlation coefficient (R),as well as the adjusted coefficient of determination(R^2) was measured. Also, another analyses ($P < 0.05$) was considered statistically significant for an EFW model [10].

The performance of all models used in this study was compared in terms of: the mean of simple error (ME) as showed equation (2), absolute of mean error (AME) equation(3), and mean of absolute percentage error (APE) was calculated using the equation(4). The efficacy of models were assessed by the number of estimates within (10%) of the ABW (true when the APE was not more than 10%) [12].

$$ME = EFW-ABW \quad (2)$$

$$AME= |(EFW-ABW)| \quad (3)$$

$$APE = \left| \frac{EFW - ABW}{ABW} \times 100 \right| \quad (4)$$

V. RESULTS

Sixty pregnant women (N=60) met the inclusion criteria for the study. The age range of the women was between (20- 42) years with a mean of 30.7 years. The range of ABW was (2500 – 4000) g, with a mean of 3390 g (SD= 375) as shown in table(2).

Table 2: Descriptive Statistics

	Mean	Std. Deviation (SD)	N
Fetal weight (FW)	2500.4000	375	60
abdominal circumference (AC)	300.4135	40.51350	60
Femur length (FL)	68.5390	6.76019	60
bipartial diameter (BPD)	82.0955	17.68200	60

Before writing down the proposed model, the data set should be satisfy the regression conditions. Data was analyzed by normal and histogram plot to know the distribution of them as shown in the following figures.

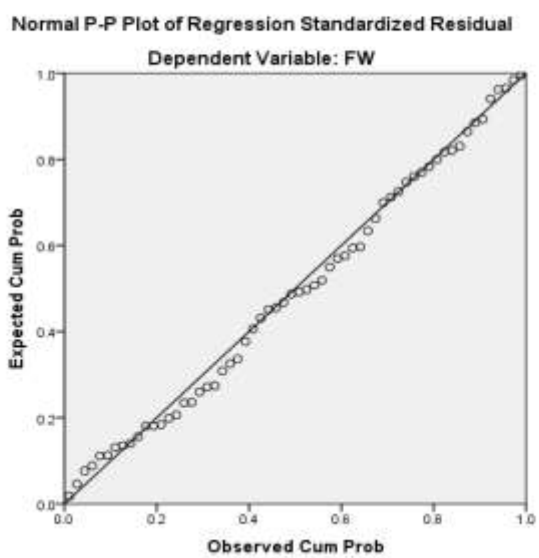

Figure 3: Distribution of dataset around the regression line

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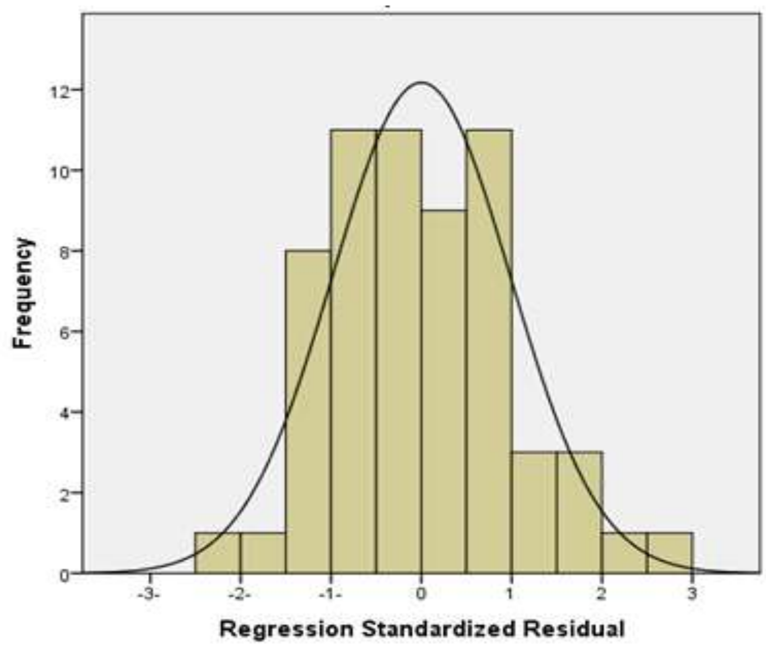

Figure 4: Show the histogram of dataset

From figure(3), it is clear that, the relation between variables is linear, as well as the correlation between DV and IVs was strong and the most of variables were surrounding the regression line, so we expect the correlation is highly positive. From the histogram analysis of dataset it is obvious that, the variables were distributed as normal distribution as shown in figure(4), also the distribution of residuals do not taken a specific shape as shown in figure(5), all of these characteristics are satisfy the conditions of linear regression.

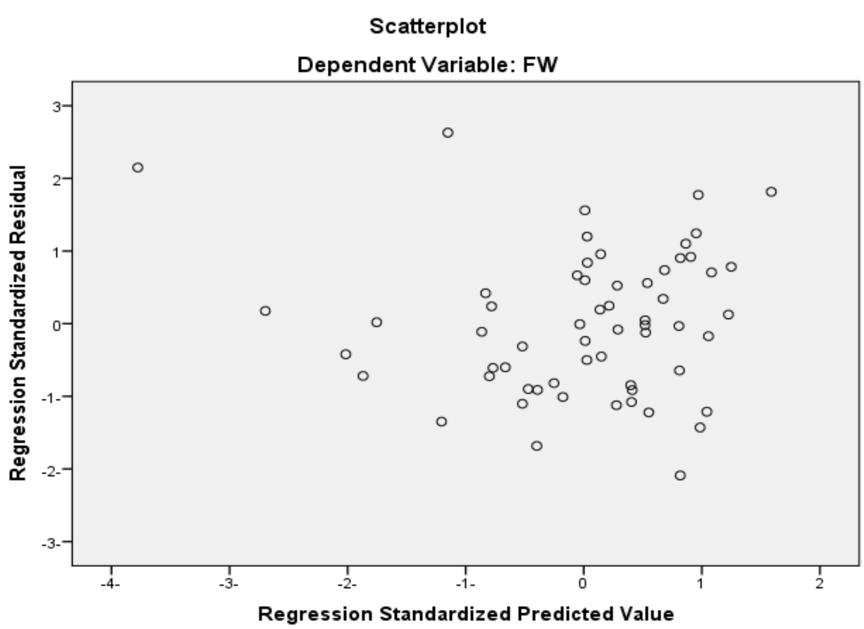

Figure 5: Scatter plot of residuals

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From figures(3,4, and 5), we can conclude that, the dataset can be modeled using multiple linear regression. For the best model the correlation among IVs should be weak (low value), while the correlation between DV variable and IVs should be strong (high positive value), table(3): shown the correlation between all variables used in this study.

Table 3: Correlations

		FW	AC	FL	BPD
Correlation (R)	FW	1.000	0.818	0.935	0.847
	AC	0.818	1.000	0.386	0.411
	FL	0.935	0.386	1.000	0.339
	BPD	0.847	0.411	0.339	1.000

From table(3), we can conclude the correlation between DV (FW), and IVs (AC, FL, BPD) was strong, while the correlation among IVs was weak, this is a good result to obtain the best regression model.

Table 4: Model Summary ^{b}

Model	R	R^2	Adjusted R^2	SD. Error of the Estimate	Sig. F Change
1	0.969 ^{a}	0.940	0.938	0.90431	0.000
a. Predictors: (Constant) AC, FL, BPD					
b. Dependent Variable: FW					

Table(4) shown the correlation (R) of model is 0.969 it is very high value as we expected firstly from distribution of variables. When the sample size (N) is large, R^2 and adjusted R^2 will usually be identical or very close, as well as the SD error of estimation was 0.90431 this is a good result. The ANOVA table (5) indicates that the model, as a whole, is a significant fit to the data ($p < 0.05$).

Table 5: ANOVA ^{a}

Model		Sum of Squares	Df	Mean Square	F	P
	Regression	10541223.845	3	3513741.282	82.878	0.000 ^{b}
	Residual	678345.355	16	42396.585		
	Total	11219569.200	19			
a. Dependent Variable: FW						
b. Predictors: (Constant), AC, FL, BPD						

Table 6: Coefficients ^{a}

Model		Unstandardized Coefficients		Standardized Coefficients	T	P
		B	SD. Error	Beta		
	(Constant)	-4763.986	494.723		-9.630	.000
	AC	2.001	.604	.338	3.997	.001
	FL	71.503	.388	.640	6.393	.000
	BPD	4.300	.876	.099	1.237	.004
a. Dependent Variable: FW						

The coefficients table(6) shown that:

- The constant, or intercept term for the line of best fit, when X= 0, is -4763.986.
- The slope coefficient are (2.001, 71.503, and 4.300) with a SD error of (0.604, 0.388, and 0.99).The (t) value = slope coefficient / standard error = (3.997, 6.393,and 1.237). This is highly statistically significant ($p < 0.05$) the usual 5% significance level.
- The standardized regression coefficient provides a useful way of seeing what the impact of changing the IVs by one SD. The standardized coefficient are (0.338, 0.640, and 0.99).

Finally, the theoretical model can be written depending on coefficients in table (6) and by using equation(1) to reach the final form as shown in the equation(5).

$$\log_{10}(EFW) = -4763.986 + 2.001\,(AC) + 71.503\,(FL) + 4.300\,(BPD) \quad (5)$$

A comparison between our proposed model equation(5), and the most famous EFW model as described in table(1) were made using the validation dataset (N=20), table(7) shown the results of comparison.

Table 7: Comparison between the performance of proposed model and other EFW models

N	GA (W)	ABW (g)	EFW (g) Proposed Model	EFW (g) HadlocK2	EFW(g) Hsieh	EFW (g) Woo	EFW(g) Jordaan
1	36	3000	3095	2914	2995	2423	2293
2	36	3294	3322	2999	2996	2424	2294
3	36	3335	3412	3089	2995	2423	2293
4	36	3360	3453	3050	2998	2324	2298
5	36	2999	3008	2912	2998	2424	2298
6	36	3098	3104	2922	2998	2422	2293
7	36	3150	3156	2917	2994	2425	2295
8	36	3000	3054	2908	2494	2424	2283
9	37	3249	3323	3121	2995	2730	2294
10	37	3070	3100	2993	2994	2427	2286
11	37	3275	3353	3000	2995	2527	2300
12	37	3468	3550	3213	2995	2727	2299
13	38	3500	3529	3212	2992	2430	2306
14	38	3813	3889	3600	2983	2279	2087
15	38	3825	3898	3632	2983	2279	2088
16	39	4000	3857	3600	2991	2432	2318
17	39	3900	3700	3345	2988	2412	2300
18	39	3964	3627	3200	2992	2430	2304
19	40	4100	4000	3938	3291	2833	2400
20	40	4000	3990	3899	3489	2935	2488

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Table 8: Errors in the prediction of fetal weights based on all models

N	Models	ME	AME	APE (%)
1	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	95 -86 -5 -577 -761	95 86 5 577 761	0.190 2.866 0.166 19.233 25.366
2	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	28 -295 -298 -870 -1000	28 295 298 870 1000	0.850 8.955 9.046 26.411 30.358
3	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	77 -237 -340 -912 -1042	77 237 340 912 1042	2.308 7.106 10.194 27.346 31.244
4	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	93 -310 -362 -1036 -1063	93 310 362 1036 1063	2.767 9.222 10.773 30.833 31.601
5	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	9 -87 -1 -575 -701	9 87 1 575 701	0.300 2.901 0.030 19.173 23.374
6	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	6 -176 -100 -676 -805	6 176 100 676 805	0.193 5.681 3.227 21.820 25.984
N	**Models**	**ME**	**AME**	**APE (%)**
7	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	6 -233 -156 -725 -866	6 233 167 725 866	0.190 7.396 4.952 23.015 27.142
8	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	54 -92 -506 -576 -717	54 92 506 576 717	1.800 3.066 16.866 19.200 23.900
9	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	74 -128 -254 -519 -955	74 128 254 519 955	2.277 3.939 7.287 15.974 29.393
10	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	30 -77 -76 -643 -770	30 77 76 643 770	0.977 2.508 2.457 20.944 25.084

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11	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	87 -257 -280 -748 -975	87 257 280 748 975	2.817 8.396 8.549 22.839 29.771
12	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	83 -255 -473 -740 -1169	83 255 473 740 1169	2.364 7.352 13.639 21.366 33.708
13	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	29 -228 -508 -1070 -1194	29 228 508 1070 1194	0.828 8.822 14.514 30.571 34.114
N	**Models**	**ME**	**AME**	**APE (%)**
14	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	76 -213 -830 -1534 -1726	76 213 830 1534 1726	1.993 5.586 21.767 40.230 45.266
15	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	73 -193 -842 -1546 -1737	73 193 842 1546 1737	1.908 5.045 22.013 40.418 45.411
16	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	143 -400 -1900 -1568 -1682	143 400 1900 1568 1682	3.575 10.001 25.225 39.200 42.050
17	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	200 -555 -912 -1488 -1600	200 555 912 1488 1600	5.128 14.230 23.384 38.153 41.025
18	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	337 -764 -972 -1534 -1660	337 764 972 1534 1660	8.501 19.273 24.520 38.698 41.876
19	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	-100 -162 -809 -1267 -1700	100 162 809 1267 1700	2.439 3.951 19.731 30.902 41.463
20	**Proposed** **Hadlock** **Hsieh** **Woo** **Jordaan**	-96 -187 -597 -1151 -1598	96 187 597 1151 1598	2.346 4.567 14.610 28.169 39.109

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Table 9: The correlation between ABW and EFW models

Model	Correlation (R)
Proposed model	0.964
Hadlock2 model	0.920
Hsieh model	0.330
Woo model	0.236
Jordaan model	0.667

VI. DISCUSSION

Accurate EFW has a great interesting in obstetrics. As the fetal weight cannot be measured directly, it must be estimated from fetal anatomical characteristics as AC, HC, FL, BPD and others. There are many regression formulae (models) used to EFW in different countries, based on one or more fetal biometry [9,13]. But, these models still given an error in estimation. In this study, a new EFW model was developed to estimation the weight of fetuses for Iraqi pregnant women using SPSS software. To satisfy the linear multiple regression conditions, the IVs (AC, FL, AND BPD) should be weakly correlated with each other, and strongly correlated with DV (FW), the distribution of variables must be as a normal distribution and should be on or very close to the regression line, as well as, the distribution of residuals should not take a uniform shape.

The results of statistical analysis in table(3) shown the correlation (R) between FW and fetal biometry (AC, FL, and BPD) were 0.818, 0.935, and 0.847 respectively, it is clear that the FW is strongly correlated with IVs, especially with FL, While correlation between AC with (FL and BPD) were 0.386 and 0.411, R for FL with AC and BPD were 0.386 and 0.339, R for BPD with AC and FL were 0.411 and 0339 respectively. That satisfy the first condition of regression.

Figure(3), shown the normal P-P plot of variables and how it's distribution on or very close to regression line, where the distance between any point and regression line refer to the difference between ABW and EFW, so the closest distance between points (IVs) and regression line indicate to form the best model for prediction of fetuses weight. Figure(4) showed the distribution of variables taken the normal distribution (Gaussian distribution). Furthermore, the scatter plot figure(5) shown the residuals did not taken the specific shape. From all figures, we conclude the second condition of multiple linear regression was satisfied.

The model summary table(2) and statistic ANOVA table(3), showed the best value of R for proposed model was 0.969. and P value was 0.00 that indicate to significant fit of data. Finally our proposed model is written using the coefficients in table (5) and general equation of multiple linear regression (equation (1)), to reach the final form as shown in equation(5).

The performance of proposed model and common used EFW models to estimate fetuses weight for twenty pregnant Iraqi women (N=20) were compared. Table(7), shown the results of EFW for eight cases with GA =36 W, and ABW between (2999-3360)g, were (3008-3453) for proposed model, (2912-3089)g for Hadlock2 model, (2494-2998)g for Hsieh model, (2324-2425)g for Woo model, (2655-2862)g for Joddaan model. The results of estimation for fourth cases with GA=37 W, ABW between (3070-3468)g, were (3100-3550)g for proposed model, (2993-3213)g for Hadlock2 model, (2994-2995)g for Hsieh model, (2427-2727)g for Woo model, and (2660-2667)g for

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Joddaan model. For two cases with GA=38 W, ABW (3500-3813)g, the results were (3529-3898)g for proposed model, (3212-3600)g for Hadlock2 model, (2983-2992)g for Hsieh model, (2279-2430)g for Woo model, and (2087-2306)g for Joddaan model. For three cases with GA=39 W and ABW between(3900-4000)g, the results were (3627-3857)g for proposed model, (3200-3600)g for Hadloch2 model, (2991-2998)g for Hsieh model, ((2412-2432)g for Woo model, and (2300-2318)g for Joddaan model. For the final cases with GA=40 W and ABW(4000-4100), the results were (3990-4000)g for proposed model, (3899-3938)g for Hadlock2 model, (3291-3489)g for Hsieh model, (2833-2935)g for Woo model, and (2400-2488)g for Joddaan model. From the all results, we can conclude the our proposed model, Hadlock2 model and Hsieh model have performance better than other models.

Table(8) shown the absolute difference between EFW and ABW (AME) for all models, for proposed model to all cases were (95, 28, 77, 93, 9, 6, 54, 74, 30, 76, 73, 143, 200, 337, 100, 96) respectively. From this result we can conclude the minimum difference between EFW and AFW was 6 g, while the maximum difference was 337 g. For Hadlock2 model the ABE were (86, 295, 237, 310, 87, 176, 233, 92, 128, 77, 231, 193, 400, 555, 764, 126, 187) respectively, the minimum AME=77 g and maximum AME=764 g. For Hsieh model the minimum AME=5 g, while maximum AME=1900 g. For Woo model minimum AME=519 g, maximum AME=1568 g. For Joddaan model, the minimum AME=701 g, while maximum AME=1737 g. Only proposed, Hadlock2, Hsieh models, show the accepted results.

The results showed the maximum difference between EFW and ABW using proposed model was only 337 g, the maximum difference between EFW and ABW using Hadlock2 model was 764 g, and the maximum difference between EFW and ABW using Hsieh model was 1900 g. from these results, it is clear that, the proposed model was better than Hadlock2 and Hsieh models to EFW. Whereas, Woo and Jordaan models show the bad results in EFW for Iraqi pregnant women, because the difference between EFW and ABW reach to 1737 g, and that given very bad diagnosis. Finally, depending on APE were displayed in table(8), and R values in table(9) it is clear the proposed model was better than other models to EFW, where the APE for proposed model between(0.190-8.501)%, approximately between(0-9)%, that means less than 10% and satisfy the acceptation of estimation. as well as the correlation between ABW and EFW by proposed model was (R=0.964). All of these statistics indicate to the good performance of proposed model.

VII. CONCLUSION

This study indicates that there was a significant difference between the ABW and EFW using most models for fetal weight estimation in Iraq, so further modification for these formulas or finding a new way for the accurate EFW still is in need. In this study a new EFW for Iraqi pregnant women was proposed, using a multiple linear regression between ABW and fetal biometry. A comparison between the performance of proposed model and other four models was done using MATLAB program, as well as, the statistical analysis of results have been done using SPPS software version 23. From the results we can conclude that the EFW by Hadlock2 model and our proposed model produced better results than other models. Furthermore, in comparison between the performance of proposed model and Hadlock2 model and depending on AME, APE, and R value, we conclude the our proposed model is the perfect model for EFW in Iraq.

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APPENDIX

All US fetuses images used in this work will be shown in the next figures.





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Figure 6: Shown some of fetuses images used in this work

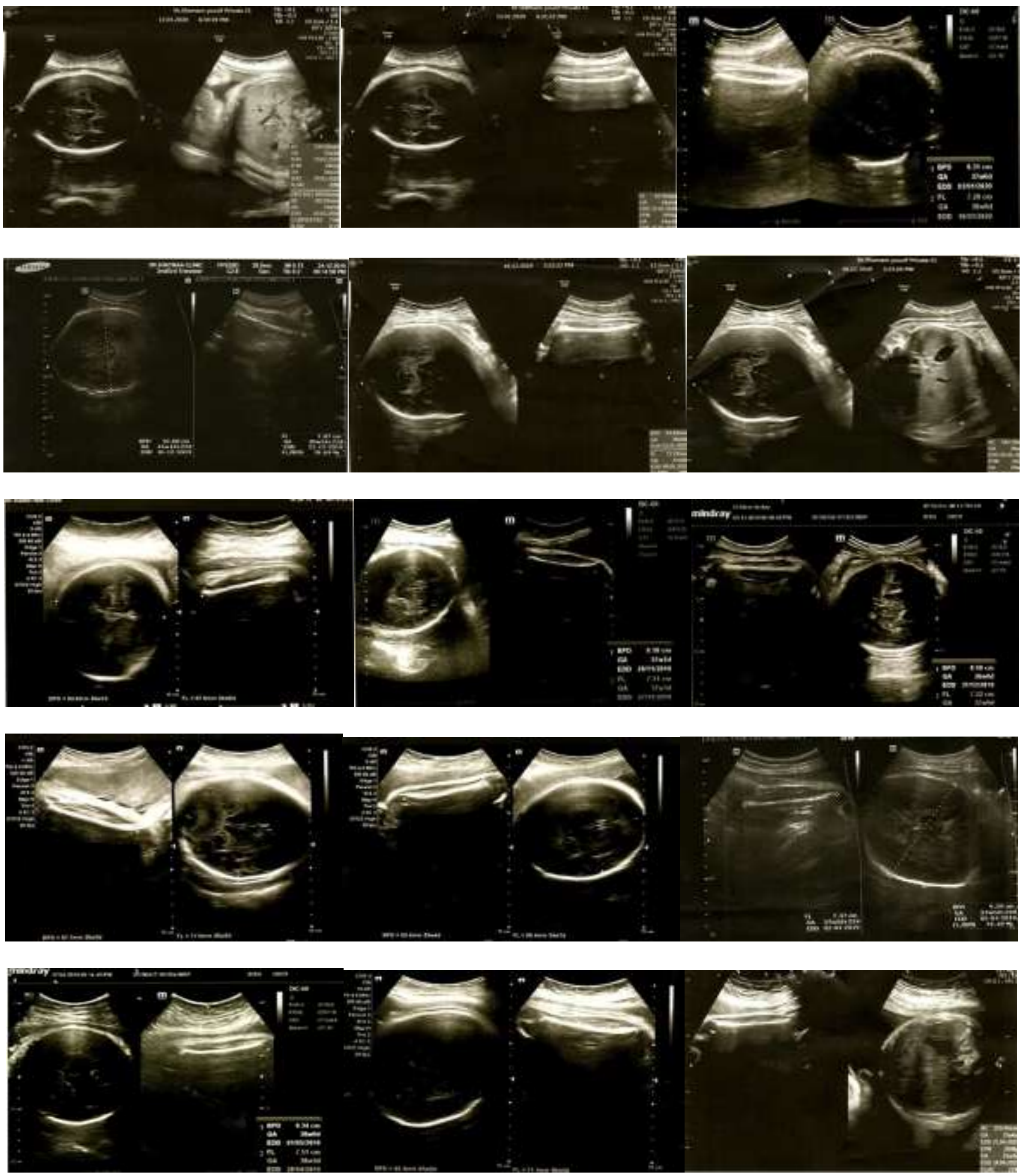

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Figure 7: Shown part of images used as a dataset in this work.

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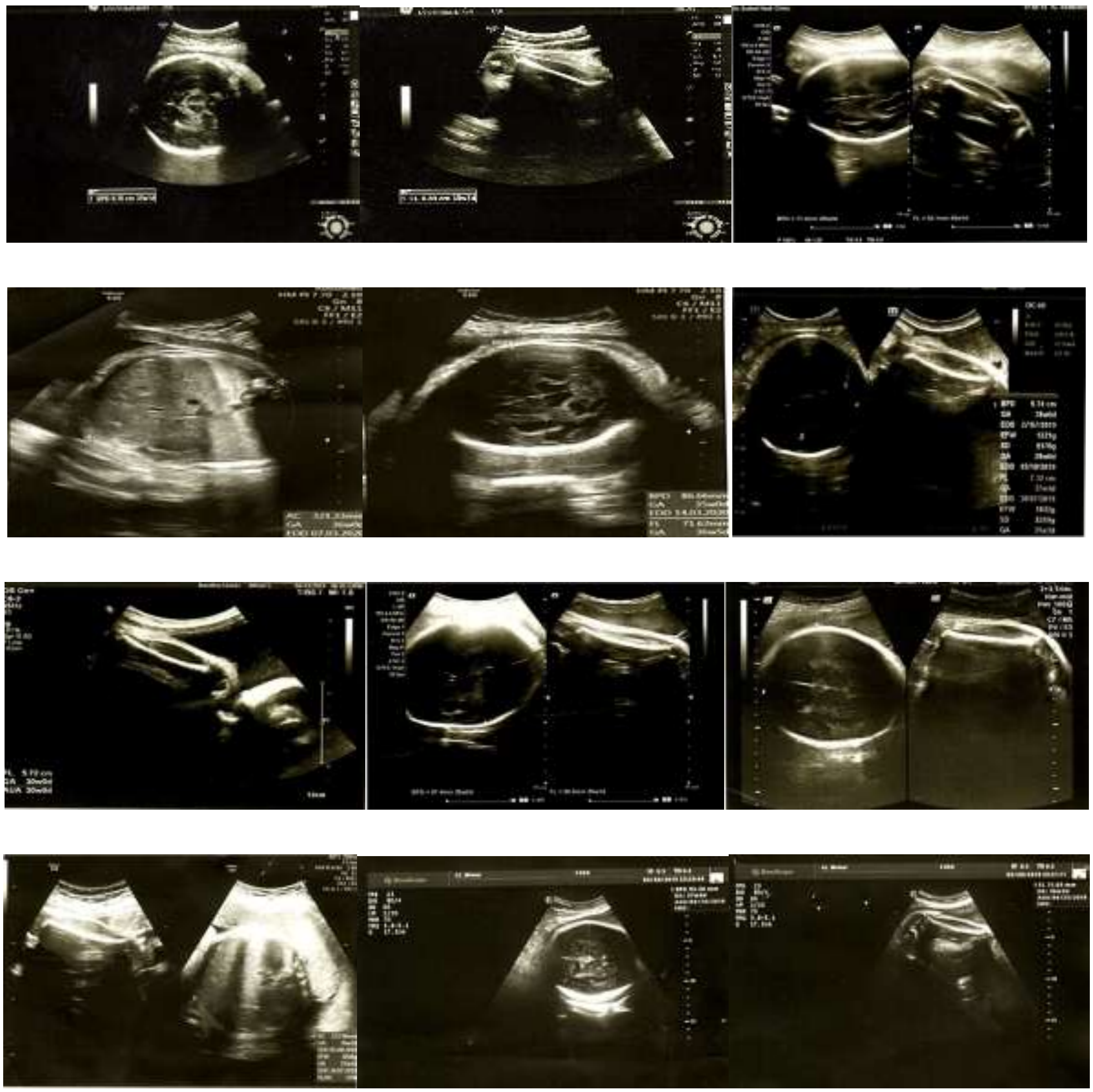
Figure 8: Shown some of US fetuses images used in this work.



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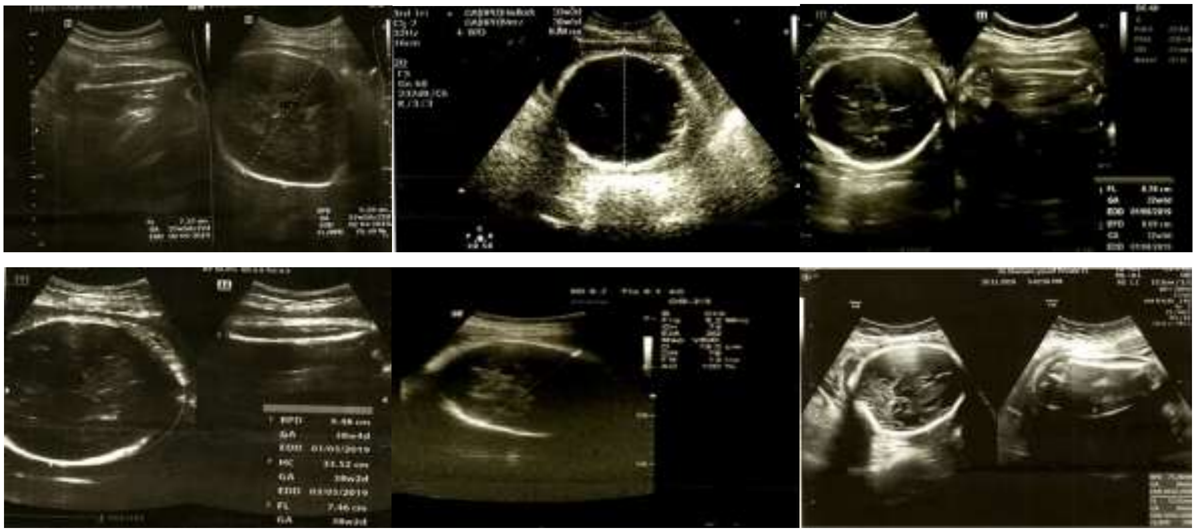

Figure 9: Shown some of fetal images used in this study.

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Figure 10: Shown the final parts of US fetuses images used in this study.

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